



# Daily Sleep Monitoring

## What is the LifeQ Sleep solution?

The LifeQ Sleep solution provides detailed analysis of an individual's Sleep Architecture, the basic structural organization of sleep, from the time they go to bed until they wake up and the sleep session ends. Traditionally, an individual would need to be monitored in a sleep clinic using sophisticated polysomnography (PSG) equipment in order to determine their Sleep Architecture. The LifeQ Sleep solution uses Photoplethysmography (PPG) and Accelerometer data obtained from most wrist-worn wearables to gain these insights

Sleep is a complex process which scientists are only now beginning to understand. Sufficient sleep is essential to a person's development, repair functions and memory consolidation. A chronic lack of sleep or poor quality thereof can increase the risk of cancer, diabetes, high blood pressure and cardiovascular disease, obesity and depression.

The first step in understanding an individual's sleep is to accurately track the amount and quality of the sleep they are getting. This is extremely challenging as the key components of this are: recognising when an individual is trying to fall asleep, when they actually do fall asleep, how they transition through various sleep stages during a sleep session and finally, when they wake up and cease trying to sleep.

## What are sleep stages?

During a sleep session, a person repeatedly cycles through Light, Deep and Rapid Eye Movement (REM) sleep. Sessions will also include short periods of awake time, which an individual may or may not be aware of. Depending on the duration of the sleep session, a person will move through several sleep cycles, each lasting about 90 minutes on average. A more detailed description of the 4 main stages is provided below:

- **Awake:** A person is conscious and alert to their surroundings.
- **Light sleep:** The brain transitions from wakefulness to sleep during this stage. Breathing and heart rate become regular and body temperature drops. During this stage, a person is somewhat alert and can easily be woken. A person may claim they weren't asleep if woken during this stage.
- **Deep sleep:** A person is less responsive to surroundings. Breathing slows down and muscles are more relaxed. It is more difficult to wake up during this stage. This is when most of the body's repair takes place, growth and development are stimulated, immune function is boosted, and energy is restored for the next day.
- **REM sleep:** The eyes move rapidly in various directions and the body is relaxed and immobile. Most dreams occur during REM sleep. This stage is thought to be important for learning and memory formation.

The LifeQ Sleep solution combines:

- **Heart Rate data**
- **Accelerometer data** to help supplement Heart Rate in providing context regarding the desire and onset of sleep.
- **Beat-to-Beat Intervals (BBI)** measured in milliseconds to provide context regarding the transition through the various sleep stages during a sleep session.

## What Sleep Outputs are provided by LifeQ?

LifeQ reports a range of features for each sleep session:

Sleep Start Time	Start time of the first sleep stage of a sleep session.
Wake-up Time	End time of the last sleep stage of a sleep session.
Sleep Stages	A detailed description of the sleep stages (Unknown, Awake, REM, Light, and Deep) and the transitions between them, including the start time and duration of each stage.
Total Sleep Time	Total time spent asleep during a sleep session.
Total Sleep Phases	Total time in each of the four phases after sleep onset.
Sleep Quality	<p>A summary of how well the person slept during the session.</p> <p>The term Sleep Quality is still poorly defined in the literature with no single accepted benchmark. LifeQ has developed a Sleep Quality score that ranges from 0-100 which is easy to interpret and thereby allows a user to engage with the score on a daily basis. The score combines a set of scientifically valid inputs namely: Total Sleep Time, amount and distribution of Awakenings and the measure of the depth of sleep (time spent in REM and Deep).</p>
Sleep Continuity	A measure of how continuous and uninterrupted a user's sleep is.
Sleep Efficiency	A ratio of Total Sleep Time (TST) to total Time in Bed (TIB) where TIB is defined as the total time spent in bed while trying to sleep. This specifically excludes time in bed when busy with other activities such as reading, and is calculated as the period between Bed Time and Wake-up Time.
Movements	Number of movements during Light, Deep and REM sleep stages.
REM Latency	Time from Sleep Start Time to the first REM stage. Individuals with a history of narcolepsy, sleep apnea and depression often have shortened REM latency periods.

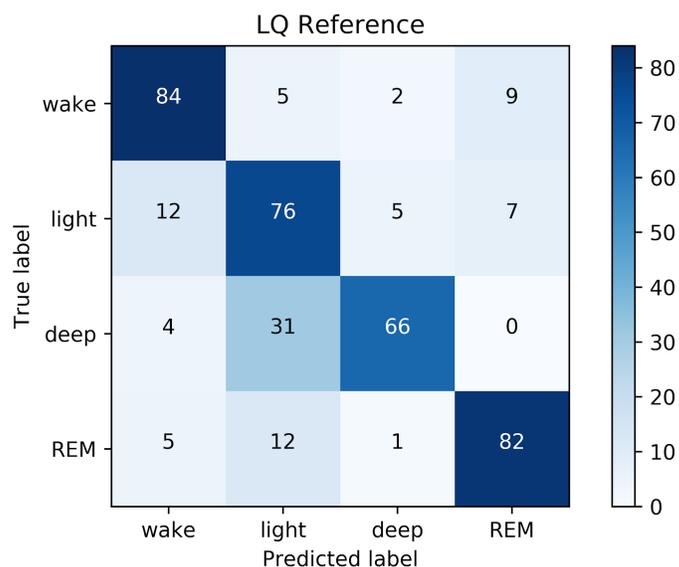
Awakenings	The number of awakenings greater than 5 minutes during a sleep session.
WASO	Wake After Sleep Onset, the total time spent awake during a sleep session.
Bed Time	The time at which a person starts trying to sleep .
Get-up Time	The time at which a person stops trying to sleep.
Sleep Onset Latency	Time spent falling asleep between Bed-time and Sleep Start Time.

## Accuracy

LifeQ has conducted validation of the sleep solution with various partners including the London Sleep Clinic and 7HourSleep in South Africa. In total over 250 individual datasets have been collected containing professionally scored PSG data alongside data generated by LifeQ enabled wrist-based wearable devices used to validate The LifeQ Sleep solution.

A summary of the results is provided below, with a detailed description of the results available in the [LifeQ Sleep Validation March 2021](#).

The simplest way of expressing sleep accuracy is in the form of a confusion matrix, which shows how often the LifeQ solution agrees with the reference device as well as how it fails when it doesn't.



**Figure 1: Confusion matrix of the LifeQ Sleep solution (LQ Reference) vs the Reference device**

**Table 1: The accuracy of Sleep solutions as reported by each market participant**

	LQ	Oura	Fitbit	Garmin	Firstbeat	SleepProfiler Auto Scoring
Kappa	0.66	0.45	0.52±14	0.54 ± 0.12	-	0.63 (range 0.62-0.65)
<b>Accuracies</b>						
Overall	77	65.7	69	69.7	66	71.3
Wake	84	59.1	69.3	73.4	62	80.9
Light	76	70.7	69.2	68.6	67	22.9 - NREM1, 79.7 - NREM2
Deep	66	53.0	62.4	68.9	67	74.9
REM	82	64.0	71.6	69.8	64	71.5

**Table 2: The accuracy of LifeQ Sleep solutions**

	Mean Absolute Deviation (MAD)	Standard Deviation (STD)
<b>Sleep Timings</b>		
Sleep Onset/Sleep Start Time	5.21	5.10
Wake Up Time	6.34	5.92
WASO	9.1	10.13
TST	20.84	20.15

## Constraints in measuring Sleep accurately

Measuring Sleep from a wrist-based device is complex and the technology has limitations owing to the nature and availability of PPG signals of sufficient quality. Accurate HR and BBI data are the most vital inputs of the LifeQ Sleep solution. The accuracy of these solutions can be seen at [Continuous Heart Rate Validation Document February 2021](#) and [Continuous Beat-to-Beat \(RR\) Intervals Validation Document February 2021](#).

During times of loss of signal due to poor device fit or lying on the device, the LifeQ Sleep solution can no longer reliably classify sleep stages and under these circumstances will output an 'Unknown stage' for as long as the problem persists.